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The portfolio balance channel: an analysis on the impact of quantitative easing on the US stock market

Imran Hussain Shah^{1*}, Francesca Schmidt-Fischer¹ and Issam Malki²

Abstract

This paper provides empirical evidence on the pass-through of quantitative easing (QE) on equity returns in the United States (US). The methodology mimics the programme's impact on investors' required returns for financial assets through the QE portfolio balance channel. This analysis of monetary policy involves using a VAR model, simulating a reduction in the share of sovereign bonds as part of central bank purchases. The findings suggest that QE caused a significant reduction in the equity risk premium (ERP) for the S&P 500. This equates to an increase in equity prices of 9.6% and acts as evidence for an active portfolio rebalancing of private sector individuals into risky assets following QE. The findings of the paper also suggest that the impact of a monetary policy expansion results in varying effects, while an expansionary policy has a stronger positive effect on equity prices with QE than without. Furthermore, we test for the presence of structural breaks in the VAR model. Firstly, using a multiple structural breaks approach, we find evidence of regime shifts and secondly accounting for the shifts in the conditional mean leads to similar conclusions as found earlier.

Key words: equity risk premium, regime shifts, quantitative easing, portfolio balance channel, equity returns.

JEL classification: E44, E51, E52, E58, G1

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1. Introduction

During the global financial crisis, the federal open market committee (FOMC) responded to deteriorating conditions in financial markets and economic growth by lowering the target federal funds rate to a range of 0% to 0.25%. With persisting slack and the policy rate at the zero lower bound (ZLB), the Federal Reserve (Fed) subsequently embarked on unconventional monetary policy. First signalled in Bernanke's Jackson Hole speech in November 2008, this measure, often referred to as quantitative easing (QE), resulted in a series of asset purchases by the central bank. By October 2014, the cumulative purchases of mortgage-backed securities (MBS), agency debt and longer-term treasury bonds, amounted to an expansion of the Fed's balance sheet to \$4.5 trillion. With the aim of reducing borrowing costs faced by a range of private individuals and companies, the channels through which QE is passed onto the real economy are open to debate. The portfolio balance channel and its potential effectiveness in reducing bond yields has been discussed, with Hamilton and Wu (2012), Gagnon et al. (2010) and D'Amico and King (2010) only being some examples. However, the programme's possible impact on equity prices is covered scarcely in academic literature and exclusively in connection with the signalling channel of unconventional monetary policy (Kiley, 2014; Rosa, 2012).

Literature surrounding QE, such as Joyce et al. (2011), concluded that equity prices did not react in a uniform way but in fact, the initial announcements induced a fall in prices. With the negative responses outweighing any modest rallies, the total effect was estimated to be approximately -3.5%. Nevertheless, the overall price increase until May 2010 amounted to 50%, evidencing some drawbacks of an event study. Most event studies carried out assign a strong focus on government bond yields with respect to the portfolio balance channel. In fact, Gagnon et al. (2010) assume this to be the primary channel through which large-scale asset purchases (LSAP) function and is based on the assumption that today's asset prices are thought to reflect investors' expectation on future asset shares. Gagnon et al. identified key policy announcement days, they then analysed the response of bond yields of different maturities. They find that QE1 announcements accumulate to a drop of 91bp in the 10-year Treasury bond yield. Furthermore, Krishnamurthy and Vissing-Jorgensen (2011) report a similar decline of 107bp cumulatively in agency debt and the 10-year Treasury bond. However, they sustain the move to be induced by a combination of the preferred habitat for longer-term 'safe' assets as well as the signalling channel.

Empirical studies exploring the feed-through of QE via the portfolio balance channel mainly focus on government bond yields. For example, Hamilton and Wu (2012) evaluated the impact

of the maturity extension programme (MEP) by modelling the impact on term structure to outstanding Treasuries. According to Hamilton and Wu (2012), the 10-year bond yield only decreases by 14bp, which suggests that central bank debt management to be of almost negligible importance. This, however, is contradicted by Gagnon et al. (2010) whose findings suggest a higher decline of 30-100bp. The latter outcome results from a model explaining the 10-year nominal term premium through measures of net supply of government bonds to the private sector and the business cycle. D'Amico and King (2010) suggest that a persistent shift in the yield curve of up to 50bp -the largest effect in longer-term Treasuries resulted from the QE1 programme. Furthermore, the literature indicates that QE has an effect on lowering interest rates, whilst evidence on the effectiveness of raising equity prices is uncertain (Kiley, 2014 2013; Rosa, 2012).

The aim of this paper is to explore the empirical evidence of an equity price impact arising from QE, through modelling its implementation in the context of private sector portfolio shifts. Joyce et al. (2011) describe a framework to responses on various asset prices, including equities in the United Kingdom (UK). This paper follows the same approach as in Joyce et al., measuring the impact of QE on stock market, however, focuses on the QE programme in the United States (US), where the government bond market is significantly larger than that of the UK³. We analyse the portfolio balance channel of QE on a variety of assets using VAR model is used to explore the relationship between relative shares and investors' required returns for major asset classes. Impulse response functions (IRFs) are then computed to simulate the negative supply shock in Treasuries held by the private sector, allowing the assessment of the portfolio balance mechanism on expected equity returns. This modelling technique consents for the disentanglement of the equity required rate of return and the risk-free government bond rate, enabling an estimation of the change in equity risk premium (ERP) induced by QE, and a subsequent translation into equity price returns. Next, a variance decomposition is conducted to account for the effect of a shock to the share on Treasuries on the other asset classes' shares and returns. Since ERP is a primary component for assessing the cost of capital and asset allocation decisions, we further investigate the impact of monetary policy before and after the implementation of QE programs, an approach developed following the 2007-2008 financial crisis. This is indeed an important topic to investigate since much of the existing literature does compare the performance of monetary policy before the financial crisis. For this purpose, it is

³ Although, the overall purchases conducted by both countries were similar in size in terms of GDP: roughly 20% of the size of the economy (Fawley and Neely, 2013).

necessary to assess the stability of the dynamic behaviour in the equity prices and the possibility of the presence of policy regimes.

In this context, we assess the robustness of our findings when allowing for the conditional mean of the VAR model to shift. This can be viewed as an extension to Joyce et al. (2012) framework as well as an assessment of the presence of policy regimes. For this purpose, we relax the assumption that the conditional mean of the VAR model is constant over time. Indeed, the literature in Belke et al. (2015), and Su and Hung (2017) on QE effects suggest the possibility of the presence of structural breaks. In this context, Belke et al. (2015) focuses on the stability of the cointegrating vector (of the relationship between the US interest rates, German interest rates and US/Euros exchange rates), which does not describe any conclusive results on whether QE caused structural breaks. Su and Hung (2017) suggests the presence of structural breaks in major stock market indices, which then incorporated to measure the effect of QE. Both studies, however, do not consider a regime shift case and the potential changing effect of different QE announcements. For example, Belke et al. (2015) does not find any conclusive evidence on whether different QE programmes cause different effects, while Su and Hung (2017) assume implicitly a homogenous effect since they capture the QE effect post breaks of the individual indices. Second, the literature incorporating breaks in a context slightly different from that of the present paper. This paper considers the case of possible shift in regimes in the VAR model. Applying Qu and Perron (2007) structural breaks test on the VAR model, we find evidence that the long run relationship between shares and returns is subject to shifts in the conditional mean. The findings suggest that these regimes coincide with important economic and financial events including the effect of one QE programmes. Thus, we account for these shifts to assess the robustness of our findings based on the standard approach.

This paper is arranged as follows. Section 2 introduces a description of the economic background behind QE with a specific focus on the portfolio balance channel. Section 3 focuses on an interpretation of the portfolio balance channel in the context of asset allocation. In section 4 and 5 the framework employed to measure the effectiveness of QE on equity returns is presented and discussed with regards to data and methodology. Section 6 presents the main findings and implications and focuses on model specification and robustness of the model including the application of Qu and Perron (2007) tests. Some concluding remarks are provided in Section 7.

2. Critical review and episodes in relation to QE in the US

2.1. Critical review

During normal market periods, central banks respond to fluctuations in output gaps and deviations from the desired inflation target by managing the prevailing short-term interest rate - the bank rate (Taylor 1993). In the wake of the financial crisis of 2007-08, the Fed reacted to deteriorating conditions in the domestic economy by cutting the federal funds rate to its effective ZLB. However, as the recession intensified and conventional monetary policy reached its limit, the central bank was forced to pursue another path if it were to provide additional stimulus. By implementing QE, a programme entailing asset purchases from the private sector, the Fed effectively expanded its balance sheet to increase bank reserves and consequently boost the amount of money in circulation. The aim to sustain the real economy in a recession is achieved by lower borrowing costs to a range of private individuals and companies, ultimately increasing nominal spending and investments (Joyce et al. 2011).

The transmission channels that enable this stimulus to influence domestic demand are strongly debated in the literature, but the most advocated amongst central bankers is the portfolio balance channel. Ben Bernanke (the former chairman of the Fed), revealed during a speech at the 2010 Jackson Hole conference: *"I see the evidence as most favourable to the view that such purchases work primarily through the so-called portfolio balance channel, [...] the Federal Reserve's purchases of longer-term securities affect financial conditions by changing the quantity and mix of financial assets held by the public"*. This theory suggests that central banks can influence the yield of an asset by changing its supply relative to that of others. In other words, by reducing the availability of the asset in question its price increases (due to the inverse relationship between yield and price). Furthermore, it implicitly recalibrates an investor's expected return on it (as higher prices lower the return an investor is hoping to receive in the future). Depending on the degree of substitutability between the asset purchased by the central bank and others in the market, investors will rebalance their portfolios into holding those assets with similar features (e.g. duration and risk), in turn affecting their respective price levels too. This aspect of the programme induces an increase in net wealth of investors, encouraging additional spending in the real economy. In the context of QE, as operated by the Bank of England and the Fed, the purchases of longer-dated government bonds leads investors to substitute their portfolio shares of sovereign securities into money, corporate bonds and equities.

For the portfolio balance channel to be effective, the asset purchased by the central bank and money ought not to be regarded as perfect alternatives (Tobin, 1958; Brunner and Meltzer, 1968). If this were the case, investors would abstain from reinvesting the capital received from assets sold to the central bank and no changes to the portfolios would be made. This concept, known as the liquidity trap or irrelevance proposition, theoretically arises if the central bank was to buy ‘one-period’ bonds as part of QE (Eggertsson and Woodford, 2003). At the ZLB, short-dated bonds are likely to bear no interest, which together with their limited credit risk, makes them the closest substitutes for money. However, by purchasing longer-dated bonds, a central bank can avoid a pure money-injecting effect, encouraging the working of the portfolio balance effect (Bowdler and Raida, 2012).

The mechanism behind the portfolio balance channel, assuming imperfect substitutability, has commonly been attributed to two possible effects in the literature, namely the preferred habitat and the duration risk. The preferred habitat effect stems from certain investors’ preference as to which type of assets to hold in terms of maturity. Institutional investors and pension funds for example, may favour holding a large share of long-dated assets to match their liabilities’ maturity. Given the strong demand for these bonds, asset purchases by the central bank therefore induce a scarcity effect in that particular yield curve segment, depressing yields and pushing up their prices. Riskier assets with similar maturity are also likely to be affected as portfolios reallocate towards them in search of returns. Because the price effect is dependent on maturities comprised in the QE programme, this effect is often referred to as the local supply effect (Joyce et al., 2012). Duration risk, or interest rate risk, on the other hand, is a concept incorporated in the price of a bond through its term premium. It is a measure of compensation afforded to investors on account of their inherent aversion towards the risk of having to hold longer maturity assets. Purchases by the central bank, however, reduce the average duration of the bonds held by the private sector and may herewith reduce the term premium in the market. Investors that wish to hold on to a certain amount of risk are ready to pay a higher price for that particular bond or shift their portfolios into riskier assets such as corporate bonds or equities (Bowdler and Raida, 2012).

2.2. Episodes of QE

The financial crisis of 2008-2009 forced the monetary policy target rate to its effective lower bound in the US and consequently the Fed was obliged to adopt unconventional monetary policies. Following the financial crisis, the Fed not only lowered the target rate from 1.0% to 0.25% but also implemented a more unconventional approach to monetary policy called QE.

Dudley (2010) illustrated that the primary aim of the QE was to reduce long-run interest rates in order to stimulate economic activity.

The Fed announced its QE1 program on 25 November 2008 and completed it on March 2010 in order to reduce mortgage discount rates and raise the credit supply for house purchases (Da Costa, 2011; Olsen, 2014). Fawley and Neely (2013) stated that the objective of QE1 was to purchase the liabilities of housing association mortgage-backed securities (MBSs) and government-sponsored enterprises (GSE). The Fed announced it was to purchase \$600 billion in total, with \$100 billion of GSEs and \$500 billion of MBSs. The QE1 program increased further in March 2009, when the Fed announced it was to buy another \$750 billion of MBSs and \$175 billion of the GSEs. The QE1 program ended on the 31 March 2010 and subsequently the Fed observed gains in the financial markets and decided to keep interest rates between 0 and 0.25% (Stroebel and Taylor, 2012).

The Fed launched its QE2 program on 3 November 2010 and completed it on 30 June 2011. The aim of the QE2 program was to reduce unemployment and lower inflation and furthermore would involve reinvesting payments from its holding in long-term bonds retaining a face value of \$2.054 trillion (Fawley and Neely 2013; Krishnamurthy and Vissing-Jørgensen, 2011). Initially, the Fed purchased \$600 billion of long-run US Treasuries until the second quarter of 2011 and continued the programme with \$75 billion of purchases monthly, however with a regular assessment of the pace and the magnitude of the program. In September 2011 after completion of QE2, the Fed announced the maturity extension program known as Operation Twist after the US economy experienced a substantial government shutdown due to reaching the debt ceiling, higher unemployment, the Eurozone sovereign debt problems resurfacing and a lower US credit rating (Bowley, 2011; Olsen, 2014). The objective of the maturity extension program was to extend the average maturity of its holdings of securities by decreasing the long-run interest rates and pushing up the short-run interest rates (Swanson et al., 2011). Moreover, the Fed also reinvested the principal payments from MBSs and agencies into MBSs instead of into Treasuries. The focus of this maturity extension program was to push long-term interest rates down and short-term rates up. The program continued until 20 June 2012 and involved monthly purchases and sales of \$45 billion of Treasury securities.

The Fed then announced the beginning of QE3 on the 13th September 2012 while the maturity extension program was also continued. The program was to boost economic growth as well as to ensure that inflation was within target. Initially, the program started with monthly purchases of MBSs to the amount of \$40 billion along with \$45 billion of longer-term US Treasuries until

there was an improvement in unemployment levels. This made QE3 quite different from QE1 and QE2, because the end of the program would be determined by “goal achievement” rather than by a given date – thereby gaining the nickname “QE-Infinity”. Simultaneously with the still ongoing maturity extension program, the joint effect was to put downward pressure on long-term interest rates, support the housing markets and ensure comprehensive financial circumstances were more accommodative. QE3 had no exogenous ending date.

3. Unconventional monetary policy in theory: the portfolio balance model

This section highlights the theoretical concepts that give rise to QE’s portfolio balance channel. The economic framework on which it is built upon is referred to as the mean-variance model and was originally by Tobin (1958). In this model, the representative agent maximises their expected utility from end-of-period wealth W_{t+1} by setting the share of wealth allocated to each asset to λ_t . Subject to an initial wealth constraint and asset supplies, the investor therefore formally faces the problem:

$$\max_{\lambda_t} U[E_t(W_{t+1})] \quad (1)$$

where the basic model as outlined above, generates the following necessary condition for a maximum⁴:

$$E_t(r_{t+1}) = z\Omega\lambda_t \quad (2)$$

where $E_t(r_{t+1})$ is the expected excess asset returns over a benchmark (usually a numeraire asset), z is the coefficient of constant relative risk aversion (CRRA) and Ω is the variance-covariance matrix of the assets’ expected returns.

Following the approach of Engel and Frankel (1984), risk aversion and the covariance matrix are assumed to be constant over time. When proceeding with these assumptions, the expected excess returns are amongst other things determined by the covariance matrix of asset returns that can be interpreted as substitutability between two assets. In other words, when varying the relative stock of two assets, the resulting change in expected excess return will be determined by the magnitude of the covariance. Additionally, the expected excess return depends on the investor’s potential inability to allocate the wealth maximising weight due to, for example, limited supply or regulatory restrictions. This results in the investor requiring a compensation in form of an expected excess return on an alternative asset to willingly holding it. However,

⁴ See Fraser and Groenewold (2001) for derivation.

policy makers can, as pointed out earlier manipulate the required rate of return by influencing the shares of assets outstanding. When the Fed adopted QE, it was designed to drive the yield on sovereign bonds so low that investors would rebalance their assets away from risk-free government bonds into higher-yielding, riskier assets (Joyce et al., 2011).

However, an application of the VAR model to the abovementioned theory would require expected excess returns to be observable. In order to grasp the effect of QE on the required rate of return as an endogenous variable, the investor is therefore assumed to have rational expectations here forth. Hence the difference between excess returns and expected excess returns is determined only by a random estimation error.

$$r_{t+1} - E_t(r_{t+1}) = \varepsilon_{t+1} \quad (3)$$

where $E_t(\varepsilon_{t+1}) = 0$ and $E_t(\varepsilon_{t+1}|\lambda_t) = 0$.

Combining equation 2 and 3 and by adding a constant term A, the basic model can be rewritten as follows⁵:

$$r_{t+1} = A + z\Omega\lambda_t + \varepsilon_{t+1} \quad (4)$$

where the vector of excess returns r_{t+1} is specified as a linear combination of asset shares in the portfolio λ_t , with weights proportional to the variance-covariance matrix of the assets' excess returns Ω and the degree of relative risk aversion z (Fraser and Groenewold 2001).

The portfolio balance model as described above, makes a number of over-simplified assumptions: one of them being that the covariance matrix and risk aversion are time invariant. It seems unlikely that these aspects would not be affected during times of financial or economic turmoil (Yellen, 2011). Furthermore, it substantially simplifies on the variables affecting expected asset returns, not capturing the influence of business cycles, portfolio performance, etc. Nevertheless, this analysis applies this approach at the basis of a VAR model in which the co-movements between expected excess returns and asset shares can be portrayed, allowing for an understanding of the effect of QE on the US stock market.

⁵ See Frankel and Engel (1984) for derivation.

4. Data description and preliminary statistics

The monthly data applied in this analysis⁶ examines the effect of the Federal Reserve Bank of St. Louis' QE policy on the US asset prices. It consists of end-of-month realized yearly returns, asset shares and dividend yields spanning from January 1984 to January 2017. As part of the portfolio rebalancing channel, four major asset classes are assumed to be available for investment: equities, investment grade corporate bonds, Treasury bonds and money. The latter takes the role of a numeraire asset and is represented by the US measure of broad money (M2).

This analysis employs the S&P 500 total return index for equities. The total return index tracks both capital gains and aggregates any cash distributions (for example dividends), which are then reinvested into the index. It therefore indicates a more precise representation of return to an investor than the price index. Similarly, total return indices are employed for corporate and government bonds, represented by the Barclays investment-grade corporate bond and US Treasury total return index respectively. Here the total return index serves a similar function to that of the S&P 500, where price variations are captured along with any coupon payments.

The total return indices above enter the analysis as excess return over money. For this purpose, the target federal funds rate, serving as a proxy for the return on the numeraire asset, is subtracted from the year-on-year (yoy) return of the indices. The upper target rate is here used in order to portray the Fed's current policy stance. It is worth noticing that this analysis employs yearly returns. As the return on an investment, the yield, is usually expressed annually, it herewith avoids any issues with annualising lower frequency outcomes. In fact, it circumvents the implicit assumption that annualising the change in monthly returns induces a recurrent shock of the same magnitude each month of the year.

Table 1 below indicates the relevant summary statistics for these calculations and reports the return on money i.e. the Fed funds target rate, over the sample investigated. At this point, it is again emphasised that due to the rational expectation assumption, the excess returns can be understood as expected excess returns.

⁶ All the information is obtained from Thomson Reuter's Datastream.

Table 1: Excess returns and money return summary statistics

	Mean	Standard Deviation	Maximum	Minimum	Kurtosis	Skewness	JB P-value
Excess Return on Equities	8.2%	16.2%	53.4%	-43.6%	0.5	-0.6	0.00
Excess Return on Corp. Bonds	6.8%	10.2%	62.8%	-15.7%	5.1	1.5	0.00
Excess Return on Sov. Bonds	5.2%	7.8%	40.3%	-10.0%	3.6	1.4	0.00
Return on Money	4.0%	2.9%	11.4%	0.3%	-1.0	0.2	0.00

The entries of the Table 1 confirm that riskier assets are characterised by a higher average return, and as expected also present a higher volatility (standard deviation). It can be observed though that the Barclays bond indices' maximum observation seems over-estimated. This can probably be attributed to initial complications, for example pricing, during the first years after inception of the total return indices. In fact, since establishment of the index in 1973 until approximately 1984, the year-on-year returns experience some enormous swings, reaching extreme levels of even 166% on corporate bonds. Consequently, we have used data starts from 1984 and excludes observations of the chaotic volatility resulting from the enormous swings prior to January 1984 for this analysis.

The asset shares of the individual asset classes are computed as percentage of the total market value over the same sample. The market value of the bonds and equities is defined as their market capitalization, calculated by multiplying the price of an asset by its outstanding securities. For the numeraire asset, however, the value of broad money enters the analysis as a representation of the market value. The latter is a measure of money supply including narrow money as well as savings deposits, money market mutual funds plus other short-term time deposits.

Fig. 1. Financial market indicators development from 1984-2017

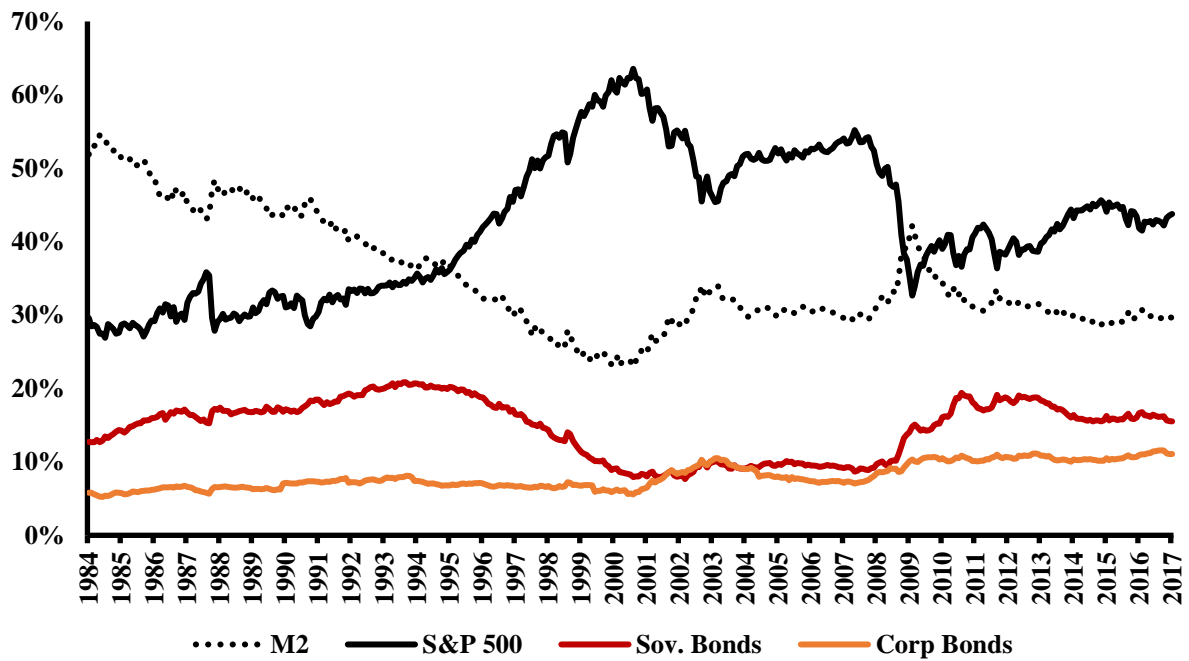
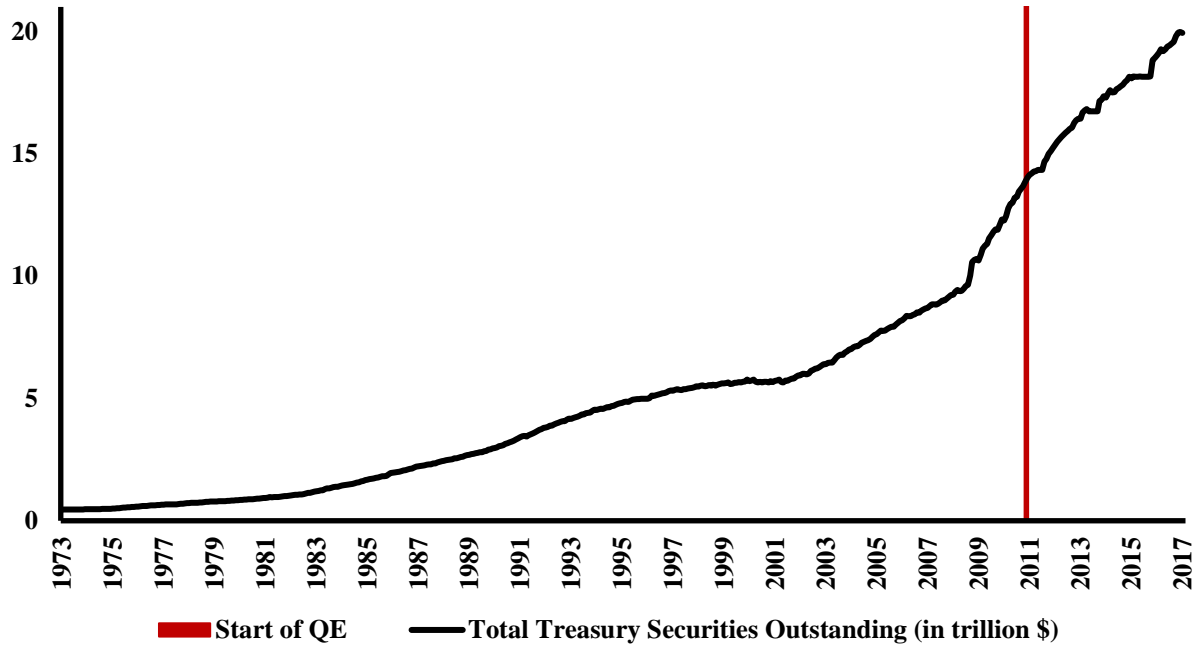


Fig. 1 shows the asset shares where the black, red and orange solid lines (black, grey and light grey when viewed in grey scale) correspond to S&P 500, the sovereign bonds, and corporate bonds respectively and the black dotted line displays M2. In line with the findings of Joyce et al. (2012), Fig.1 illustrates a strong opposite relationship between equities and broad money. Interestingly, the share of equities and particularly Treasuries, increased significantly in the midst of the financial crisis and thereafter. For equities, this effect is possibly mainly due to capital gains, keeping in mind that the market value index is a function of share prices amongst others. For Treasuries, in contrast, this development is most likely to be indorsed to an increase in issuance to match the purchases of the Fed.

Fig. 2. Total Treasury securities outstanding and QE



As Fig. 2 depicts, the issuance of Treasuries picked up significantly in the middle of 2008 from \$9.5 trillion to approximately \$20 trillion in October of 2016, showing a more than doubling of the government bond market over the duration of the global financial crisis and QE programme. Considering that the purchases by the Fed only comprised \$1.6 trillion of Treasury securities, this implies a substantial expansion in the market value and probably explains the increase of the share in government bonds as shown in Fig. 1.

5. Estimation methodology

This section emphasis entirely on the effects of the QE programme on the equity market in the US. As mentioned in the introduction, this is done by assessing the effect of the portfolio balance channel via a VAR model. This consents for an examination of the relationship among the relevant variables and their autoregressive components, which are carefully selected in the context of the QE transmission channel. IRFs can then quantify the time path of a reduction in the availability of government bonds, i.e. a negative shock to the share in US Treasuries, on the other exogenous variables. Further analysis allows for an understanding of what implications the outcomes from the IRFs have on the US equity markets. A variance decomposition is then conducted to determine the relative significance of a QE shock to the share in government bonds in explaining the variability on the other variables in the model. Furthermore, we investigate

the validity of our findings when permitting for the conditional mean of the VAR model to shift.

5.1. The VAR model: A portfolio balance channel and stock market

We estimate a VAR to analyse the portfolio balance approach on a variety of assets to investigate the impact of monetary policy on both asset shares and excess returns. The parameters are estimated for multi equations by OLS. Our VAR (ρ) take the following reduced-form:

$$y_t = a_0 + \sum_{i=1}^{\rho} A_i y_{t-i} + Bx_t + u_t \quad (5)$$

where y_t is a vector of ρ endogenous random variables, a_0 is the fixed vector of intercepts, x_t is the vector of exogenous random variables, A_i and B are fixed coefficient matrices, and u_t is vector of errors with time invariant covariance. The y_t vector includes of investment-grade corporate bonds, government bonds and equities, where money enters the model as the numeraire asset. Moreover, this paper contains exogenous variables intended to detain the business cycle. For this purpose, the annual growth rate of industrial production (IP) and a measure of inflation are thought to be applicable. Assuming these variables to be predetermined, while is a strong assumption as it prevents inflation and economic growth to be affected by the endogenous interest rates. In the context of QE and bearing in mind that the Fed's mandate explicitly targets price levels, inflation will therefore be excluded from the analysis.

An IRF analyses changes in one variable's error term and assesses the feed-through to the other variables in the system. In VAR models, changes in a variable enter the analysis as nonzero errors. In this context the nonzero element of u_t is connected with a change to the share of government (sovereign) bonds. The autoregressive property of the VAR then ensures that this change will be carried forward to the other endogenous variables in the periods to come, but problems with explanation of IRFs could arise if the error terms are correlated. In fact, the variance-covariance matrix Σ_u is non-diagonal, meaning that an exogenous shock to variable i is simultaneously associated with a shock to any other endogenous variable j ⁷. Because this analysis is interested in dividing the impact of a shock to the share in government bonds, the VAR can be rewritten such that the shock to a certain variable is uncorrelated to the others and therefore the only innovation affecting the system. An application of identification restriction

⁷ See Table T1 in the Appendix

is the Cholesky decomposition. This essentially pre-multiplies the left-hand side of the equation by the inverse of a lower triangular matrix A , comprising the standard deviations of u_t . This results in a diagonal variance-covariance matrix Σ_ε .

$$\varepsilon_t = A^{-1}u_t \quad (6)$$

where A is equal to:

$$A = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \end{bmatrix}$$

Formally this restriction is computed by setting zero-restrictions on $a_{ij} = 0$ for $i < j$. The transformation reflects that a shock to variable i has no contemporaneous effect on the other variables $i > j$, but rather exhibits a recursive behaviour. This implies that the first variable in the VAR is only affected contemporaneously by the shock to itself, while the second variable is affected by the shocks to the first variable and the shock to itself, etc. Given this importance of the relative ordering of variables within the matrix, one problem with this procedure is that an appropriate ordering cannot be determined by statistical methods. It is therefore subjectively selected which variables are most endogenous, relative to what the economic background of the model implies.

When studying the portfolio rebalancing effect, it is presumed that the asset shares are the most exogenous followed by the returns. Within the first group the following order is assigned to the variables: equities, investment grade bonds and government bonds. Returns, in contrast, are arranged as government bonds first, investment grade bonds second and equities last. The restriction may be motivated as follows: the shares are the variables affected by QE purchases and may therefore be the only ones that have potential impact on all others. The other variables, are by ordering subsequently less exogenous and are simultaneously assumed not to respond to the monetary policy shock in the same month, suggesting a slower feed-through. It is herewith suggested that investors with relatively risk-free portfolios, such as pension funds and insurance companies, will shift into slightly riskier assets, such as corporate bonds and equities to meet return requirements (Joyce et al., 2017). The prices of these assets are affected correspondingly.

5.2. The expected excess return and the equity risk premium

The model captures the change in expected excess return on the various asset classes induced by the central bank's programme. At this point, it is worth emphasising again that in the framework of this analysis the expected excess return is understood as required rate of return and is not to be confused with actual price returns. Although the resulting fluctuations in expected excess return from the IRFs to bonds can be understood as a revision to their yield, the interpretation for equities, however, is not quite as straight-forward. The equity required rate of return (r^{eq}) is defined as the sum of the risk-free government bond yield (r^f) and the equity risk premium (ρ^{eq}) and expresses the compensation investors involve for bearing the additional risk from holding this asset.

Following the Capital Asset Pricing Model (CAPM) introduced by Sharpe (1964):

$$r_t^{eq} = r_t^f + \rho_t^{eq} \quad (7)$$

In order to put the results from the VAR into context and grasp the price effect of QE on the stock market, the analysis by Joyce et al. (2012) attempts the conversion of their IRF results into equity returns by using a dividend discount model. This paper proposes a different, although similar approach to deriving price returns. This is done by disentangling the IRF's resulting shock to equities' required return into its components, the ERP and the risk-free rate. Following Equation 7, this analysis deducts the change in expected sovereign bond yields from the change in expected equity excess return resulting from the IRF. The resulting difference in expected ERP, is thereafter interpreted to a respective change in the price level given the historic relationship between ERP and equity prices as follows.

5.3. The impact of QE on equity price returns

The historical ERP can be derived by the dividend yield method, also known as the Gordon growth model (Gordon and Sharpio, 1956). The theory suggests that the excess return of a stock can be calculated by incorporating the dividend yield to a constant dividend growth rate.

$$r_t^{eq} = \frac{D_t}{P_t} + g \quad (8)$$

$\frac{D_t}{P_t}$ is the dividend yield (dividend expressed as percentage of current price of the stock index) and $g(\Delta div)$ constant dividend growth rate. Rearranging the above and substituting equation 7 into it, the ERP can be calculated as follows:

$$\rho_t^{eq} = \frac{D_t}{P_t} + g - r_t^f \quad (9)$$

At this point, an assumption requires to be made on how long-term dividend growth is defined. Herewith, the latter is set equal to the yoy dividend growth of the sample average (8.5%). Due to long-term dividend growth being constant, changes in the ERP are therefore solely induced by changes in the risk-free rate and the dividend yield prevailing in time t . The advantages of this approach is its intuitive nature. However, it relies on a perpetuity assumption and is therefore sensible to which one is adopted.

The ERP is a key factor in deciding how much wealth an investor is willing to attribute to this specific asset class. On the basis that the value of an asset is determined by the present value of expected cash flow and discounted back to estimate a current price level, the risk-free rate and ERP play a crucial role. The risk aversion of an investor herewith determines how much they are willing to pay for a certain asset – the higher the perception of risk, the higher its price and consequently the lower the willingness to pay for the same set of expected cash flows (Brealey et al. 2008).

Fig. 3. Historical equity risk premium and price index

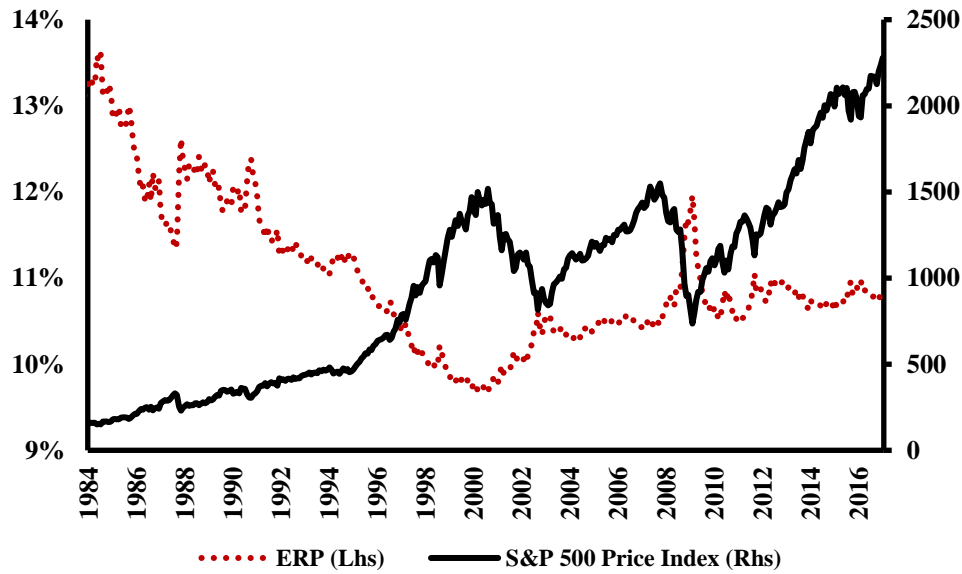


Fig. 3 clearly suggests an inverse relationship between the calculated ERP and the price index. This association can also be confirmed by the regression outlined below (Neely et al. 2015).

$$\Delta p_{t,t-1}^{eq} = c + \beta \Delta \rho_{t,t-1}^{eq} + u_t \quad (10)$$

In this way, a conclusion on how changes in the ERP induced by QE, alter yoy equity price returns (p^{eq}) for the S&P 500, can be drawn. The 1% change in ERP is scaled to the purchases conducted by the Fed for a more accurate estimation. Because stock indices are usually quoted in price returns, applying the price index rather than the total return index, circumvents the

drawback of having to disentangle the return in terms of capital gains from other cash distributions (Brealey et al. 2008).

5.4. Regime shifts and stability of the VAR(p) model

We also investigate the stability of the VAR model and examine whether there exist regimes consistent with economic or financial events that may prompt monetary policy regimes in the US. In the previous exercise, we assumed constant conditional mean in the VAR, which seemed to exhibit residuals spikes that may lead to regime shifts. accounted for the effect of announcing implementing monetary policy, which is captured by a dummy variable specific to the announcement date. Thus, is, we relax the assumption of constant conditional mean in the VAR and allow the system to shift. However, does not capture the effect of the policy itself on the VAR model and its parameters. In other words, we aim to test for the presence of structural breaks on the VAR, which may indicate indicating a response of the model's parameters to economic and financial changes. in in monetary policy. In order to test for the presence of such these shifts, we test for the presence of monetary policy regimes in the VAR model.

We implement Qu and Perron (2007) (QP, henceforth) test to identify structural breaks in a multivariate context. QP introduced a multiple structural breaks test that can be applied to multivariate regressions and considers a very general model. This test is an extension of the previously developed by Bai and Perron (1998, 2003) that considers the null hypothesis of l breaks versus the alternative of $l+1$ breaks for linear (univariate) regression. In our case, we deal with a VAR model that is characterized by stationary long run relationships, and thus, QP can be a suitable test to identify break dates in the system. QP suggest a range of test statistics, which includes: the $\sup LR_T$, the sequential test and the double maximum tests. The $\sup LR_T$ formally defined as:

$$\sup LR_T(m, p_b, n_{bd}, n_{bo}, \varepsilon) = \sup_{(\lambda_1, \dots, \lambda_m) \in \Lambda_\varepsilon} 2[\log \hat{L}_T(T_1, \dots, T_m) - \log \tilde{L}_T] = 2[\log \hat{L}_T(\hat{T}_1, \dots, \hat{T}_m) - \log \tilde{L}_T] \quad (11)$$

Where m is the maximum number of breaks found, $(\hat{T}_1, \dots, \hat{T}_m)$ are the Quasi Maximum Likelihood Estimator estimates of dates (partitions) using the partitions defined in $\Lambda_\varepsilon = (\lambda_1, \dots, \lambda_m)$ and ε is the trimming rate or minimum distance between each partition. Testing the changes can be done sequentially. Formally, the test statistic can be written as:

$$SEQ_T(l+1 \setminus l) = \max_{1 \leq j \leq l+1} \sup_{\tau \in \Lambda_{j,\varepsilon}} l_{r_T}(\hat{T}_1, \dots, \hat{T}_{j-1}, \tau, \hat{T}_j, \dots, \hat{T}_l) - l_{r_T}(\hat{T}_1, \dots, \hat{T}_l) \quad (12)$$

where: $\Lambda_{j,\varepsilon} = \{\tau; \hat{T}_{j-1} + (\hat{T}_j - \hat{T}_{j-1})\varepsilon \leq \tau \leq \hat{T}_j + (\hat{T}_j - \hat{T}_{j-1})\varepsilon\}$.

First, we estimate breaks over the sample period endogenously. Within the VAR, we allow for all the coefficients in the conditional mean to change. Subsequently, we are able to analyse the VAR properties for every identified regime.

6. Empirical analysis

6.1. Model specification: unit root tests and VAR (p)

In the context of the VAR model, failure to demonstrate stationarity would lead shocks to the system, not only to be persistent through time, but also to propagate. We analysis the time series properties of the variables by using the unit root tests that include the extension of the M class tests analysed in Ng and Perron (2001) and the feasible point optimal statistic of Elliot et al. (1996). Hence, the data is tested for the null hypothesis of a unit root at level with constant. The resulting test-statistics exceed the critical value (in absolute terms), rejecting the null hypothesis of the excess returns having a unit root. Table 2 indicates that all asset returns and shares are found to be stationary at level.

Table 2. Unit root test results

	DF-GLS	PP	MZa	MZt	MSB	MPT
Excess Return on Equities	-3.42**	-4.50**	-31.21**	-3.94**	0.13**	0.83**
Excess Return on Corp. Bonds	-3.54**	-4.17**	-10.27**	-2.24**	0.21**	2.48**
Excess Return on Sov. Bonds	-3.56**	-3.84**	-26.73**	-3.62**	0.14**	1.04**
Share of Equities (YOY%)	-2.86**	-3.92**	-16.60**	-2.86**	0.17*	1.54**
Share of Corp. Bonds (YOY%)	-3.29**	-3.66**	-30.92*	-3.93**	0.12*	0.80**
Share of Sov. Bonds (YOY%)	-3.54**	-3.11**	-15.26**	-2.70**	0.18*	1.85**

Note: ** indicate the level of significance at 5%. The unit root tests with structural breaks in essentially trend-stationary series, namely, (MZt) Elliott-Lothman-Stock, (MZa) Ng-Perron (MSB) Silvestre-Kim-Perron, SKP-MZT Silvestre-Kim-Perron and PP- Z α Phillips-Perron.

We estimated the VAR model by using monthly data on a sample from 1984M1 to 2017M1. It is commonly known that the results of a VAR analysis are sensitive to the lag-length selected. In order to construct accurate IRF, it is hence crucial to account for this (Eadie et al., 1971). The number of lags has been set using Akaike's information criterion (AIC), the Schwarz criterion (SBIC) and Hannan-Quinn criterion (HQ) refer to a VAR model with 2 lags reported in the Appendix Table T2. To check for autocorrelation of the residuals, we plotted the residual

autocorrelations and estimated the Lagrange Multiplier (LM) test⁸. The result derived from the LM test did not confirm autocorrelation and come to the same conclusion as the correlograms reported in the Appendix Fig. F1. Finally, to check the VAR(2) stability, Table T2 in the Appendix depicts that no root lies outside the unit circle, which confirms stability (Lütkepohl, 2013). These results are an important confirmation that the selected lag-length for the model is appropriate, and it is therefore considered as adequate to proceed with structural analysis of the IRFs and variance decomposition.

6.2. The impulse response functions

We employ an impulse responses analysis to study the response of excess returns and asset shares to the shock of sovereign share. This latter is assumed to take three forms. First, we consider the form when the relationship is governed by a constant conditional mean. This form refers to the situation when the response of excess returns and asset shares to the shock of sovereign share is constant and the same over time. We relax the assumption of constant conditional mean and allow for the possibility of structural breaks and regime shifts. In this context, shocks of sovereign shares might prompt different responses from excess returns and excess shares due to shifts in the conditional mean of the model. The sovereign share can be interpreted as response to economic and financial events such as the QE shock, namely a negative reduction in the share of sovereign bonds available to the markets.

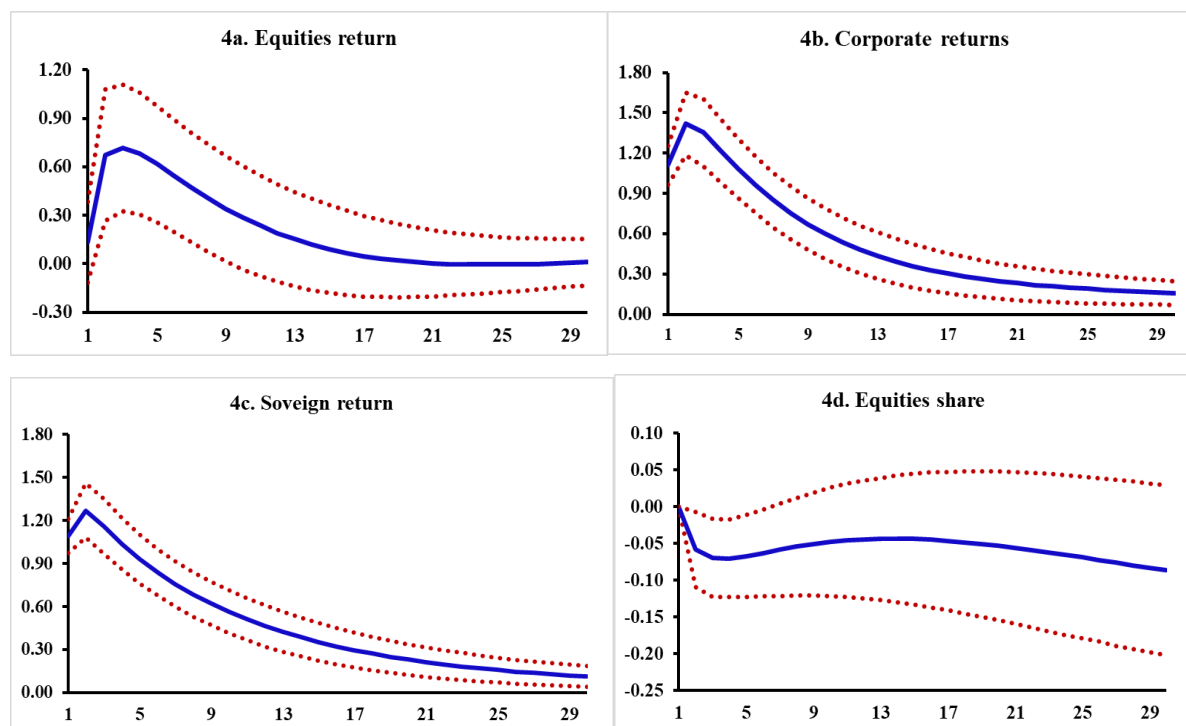
Fig. 4 shows the IRFs the red dashed lines show a one standard error 95% confidence band around the estimates of the coefficients of the IRFs. Fig. 4a-4c shows the responses of returns for a one-standard deviation fall in the share of sovereign (QE shock). The QE shocks (share of sovereign falls) have, as expected, a positive and highly significant effect on the equities returns, the corporate return and the sovereign return. Our findings are consistent with those of Fratzscher et al. (2013), who highlight the positive impact unconventional monetary policy has on the expected excess returns in the US. These findings are also in line with the view that suggest the typical response of the stock market to the Fed's announcement, results in a rise in excess returns when the policy is expansionary and vice versa. This is due to the positive effect of an expansionary policy on investors' expectations.

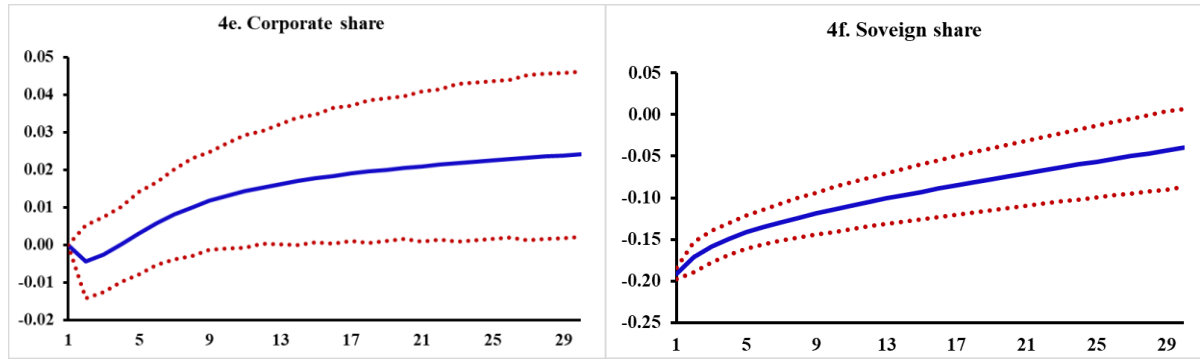
The share of US government bonds decreases meaningfully at inception of the central bank's intervention, slowly returning back to its original value, showing a gradual fading off of the shock reported in the Fig. 4d-4f. This is in line with the theory that central bank purchases

⁸ See Table T3 in the Appendix.

decrease the available supply of bonds to be purchased. Whilst the share of investment grade bonds does not seem to be affected by the programme at all, equities shares strangely also experience a decline. Although, this result is not compatible with the portfolio balance theory, it is consistent with the findings of Joyce et al (2012) and might reflect the strong inverse relationship in shares of equities to broad money over the sample. However, both corporate bonds and equities exhibit an insignificant IRF, suggesting the unimportance of this shock to these shares. Moreover, it can be noticed that the effect from a reduction in governments bonds abates only very slowly in all variables. In fact, an alteration of relative asset shares triggers a portfolio rebalancing into riskier assets, whilst adjusting the expectation of future returns down. This is reflected as a decline in bond yields of similar magnitude for both government and investment grade securities, as well as a shrinking of the required rate of return on equities. Whilst the initial reaction to a one standard deviation shock leads to a decline in sovereign and corporate bonds yields of 1% and 2% respectively, it is already reverted to half the size after 8 months. Nevertheless, the government bond yield seems to reduction at a faster pace that the required return on equities.

**Fig. 4. Expected excess returns and asset shares responses to fall in sovereign share
Form 1: Constant conditional mean**





6.3. Variance decomposition

In addition, Table 4 shows the variance decomposition of shares and returns, which highly supports our initial findings. We notice that, simultaneously, the role of QE in explaining expected excess returns is important in the short run. The monetary policy shock accounts for sizable components of the variation in the sovereign (21%), the corporate (16%) and equity returns (4%). In contrast, sovereign shocks explain only 0.44% and 1.47% of the variation of equity and corporate shares respectively. This is in line with the corresponding results of impulse responses analysis. Because QE play a rather import role in excess returns.

Table 4. Variance decomposition to shock of QE

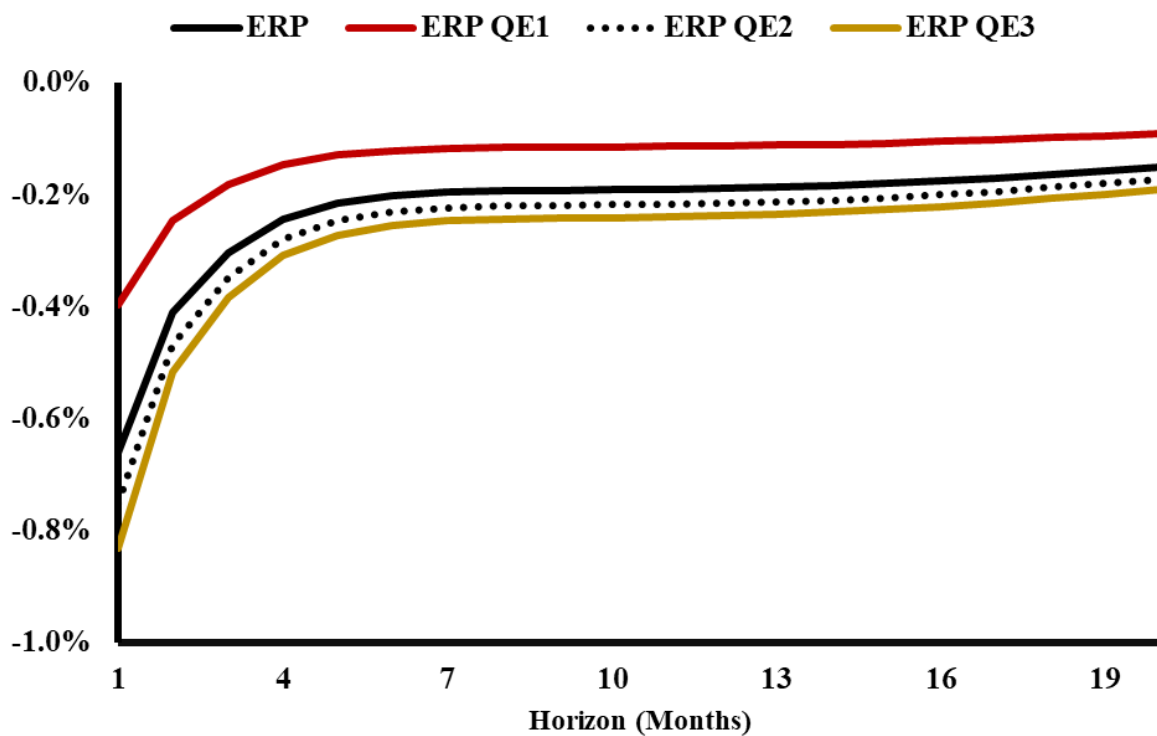
Period	Eq_share	Corps_share	Sov_share	Sov_return	Corps_return	Eq_return
1	0.00	0.00	33.54	16.96	11.29	1.18
2	0.18	0.21	30.45	18.32	12.99	2.02
4	0.39	0.34	27.28	18.98	14.08	2.55
6	0.45	0.45	25.21	19.34	14.57	2.91
8	0.46	0.60	21.66	19.65	14.89	3.35
10	0.44	0.73	21.41	19.94	15.11	3.61
12	0.42	0.85	19.95	20.19	15.26	3.78
16	0.37	0.97	16.77	20.61	15.41	3.90
20	0.35	1.09	14.00	20.90	15.47	3.97
24	0.36	1.21	13.88	21.09	15.49	4.01
28	0.41	1.34	09.88	21.21	15.52	4.03
30	0.44	1.47	09.10	21.25	15.53	4.04

6.4. The equity risk premium and equity price returns

As pointed out in the methodology, the ERP can be calculated as the difference between the equity yield and the risk-free rate (see equation 7) and herewith suggests a gradual response in the ERP. The results from this simulation of a one standard deviation show are translated to a decline in the share of Treasuries ranging from approximately \$850 billion to \$1.4 trillion using the month of inception of the three QE programmes. In order to grasp a more precise estimation,

this value is then multiplied by the ratio of the actual size of the Treasury market to the market value of the Barclays Treasury index⁹. The resulting value is then used to scale the three QE programmes. We computed the ERP by using impulse responses and scaling as explained in the Appendix Table T5. Fig. 5 depicts that the unconventional monetary policy shocks impact the ERP negatively, where an average reduction in the ERP of 0.23% can be observed for each of the three programmes after 12 months. It implies that the changes in the ERP have a negative effect on the returns of the S&P 500 and this leads to a decrease in the amounts of cash invested in riskier assets such as stocks. The findings are qualitatively similar to that of Poshakwale and Chandorkar (2016) and Bredin et al. (2007) for the equity market.

Fig. 5. Equity risk premium implied from impulse response functions



The range of estimates found can be plotted into price returns by the computed historical ERP. The result shows that a 1% rise in the ERP from one period to the other corresponds to a 4.14% price reduction of the S&P 500¹⁰. Alternatively, a reduction in the ERP suggests a positive impact on annualised equity returns. This is consistent with the evidence from Fig.3, where a clear inverse relationship between these two variables is revealed.

⁹ See Table T5 in the Appendix.

¹⁰ See Table T6 in the Appendix

The potential impact on equity prices is estimated, where the ERP reaches its minimum after 18 months. This occurs in order to allow the market to fully price in the shock, rather than just considering the instant impact and foregoing a potential slower feed-through of QE to equity markets. In the Table 5 the yearly equity price return contributions from each of the QE programmes is exhibited.

Table 5. Estimated impact of QE on yearly S&P 500 returns

Response in S&P 500 price index	
QE 1 (\$300 bn)	1.9%
QE 2 (\$600 bn)	3.7%
QE 3 (\$755 bn)	4.0%
Cumulative rise	9.6%

With the last programme being the most effective in raising equity prices, the evidence suggests only a minor difference in effect between the QE2 and QE3. Overall, the portfolio balance effect induced by QE seems to have successfully contributed to a boost in equity prices by 9.6% over the duration of the programme. The findings of this paper are in line with recent literature that finds a positive relationship between monetary policy expansion and stock market (Laopodis, 2013; Liu and Asako, 2013; Poshakwale and Chandorkar, 2016).

Furthermore, we explore the response of the ERP to monetary policy shocks before and after the introduction of QE. For this purpose, we divide the sample into two groups, with the pre-QE sample running from January 1984 to November 2008 and the post-QE sample from December 2008 until January 2017. Table 6 indicates the response of the ERPs of the sovereign shares, with and without QE. We can see that the ERPs respond negatively to the monetary policy shocks before and after QE. However, there is a sizeable difference between the responses of the ERPs to expansionary monetary policy shocks over the two periods. This is in line with the findings of Karras (2013) that the effectiveness of monetary policy shocks decreases with their magnitude.

Table 6. Equity risk premium implied from impulse response functions before and after QE

	Before QE	After QE			
	ERP	ERP	ERP QE1	ERP QE2	ERP QE3

1	-0.75%	-0.63%	-0.38%	-0.71%	-0.79%
2	-0.60%	-0.03%	-0.02%	-0.03%	-0.03%
3	-0.52%	-0.02%	-0.01%	-0.02%	-0.02%
4	-0.42%	-0.09%	-0.05%	-0.10%	-0.11%
5	-0.35%	-0.13%	-0.08%	-0.15%	-0.17%
6	-0.30%	-0.19%	-0.11%	-0.21%	-0.23%
7	-0.25%	-0.23%	-0.14%	-0.27%	-0.29%
8	-0.21%	-0.26%	-0.16%	-0.30%	-0.33%
9	-0.18%	-0.27%	-0.16%	-0.31%	-0.34%
10	-0.15%	-0.27%	-0.16%	-0.30%	-0.33%
11	-0.13%	-0.25%	-0.15%	-0.29%	-0.32%
12	-0.11%	-0.23%	-0.14%	-0.26%	-0.29%
Average	-0.33%	-0.22%	-0.13%	-0.25%	-0.27%

Finally, we further examine the impact on annual S&P 500 returns after QE in order to compare it without QE. Table 7 reports that individual and cumulative rises in the S&P 500 returns are about 13% after QE, which is significantly higher than returns without QE. One possible explanation for the size asymmetric response is that during QE, the Fed purchased high quality fixed income securities provided by central bank reserves hence effectively replacing relatively illiquid money with liquid cash reserves. This led to a fall in both short and long-term bond yields so leading to higher excess equity returns.

Table 7. Estimated impact of QE on yearly S&P 500 returns after QE

	Response in S&P 500 Price Index After QE
QE 1 (\$300 bn)	2.60%
QE 2 (\$600 bn)	4.94%
QE 3 (\$755 bn)	5.46%
Cumulative Rise	13.0%

6.5. Empirical evidence of regime Shifts

The estimated break dates are reported in Table 8 below. The value of the SupLR test reports an estimated value of 600.16, which is greater than the 1% critical value. The WDmax and *SEQ* tests confirm that the number of breaks identified is the same as the maximum number allowed (e.g. 3 breaks allowed). The dates identified coincide with the post QE in one occasion including the QE in 2008, which is estimated as the final break. The first and second break

coincide with the post market crash in 1987 and post Asian financial crisis in 1998, respectively. Thus, the break dates we estimated using the QP approach do not cover all the QE announcements, but captures key events.

This is typical when using structural break tests that identify breaks endogenously using computational algorithms as argued by Crafts and Mills (2017). In the context of QP test, this could be due to the nature of the procedure and algorithm implemented to identify the breaks. First, the QP approach allows for common breaks in the system, which is its strength and at the same time a restricting feature. This latter imposes a common date of the occurrence of shifts in regimes on all the equations in the system, which does not necessarily reflect the true break date in each equation of the system. Second, as argued by Crafts and Mills (2017), the properties of this class of structural break tests in dynamic systems is yet to be fully established, which may explain failing to identify the exact date. Nonetheless, given the stationarity property of our data, the break dates may be useful as a guide to approximate the effect of regime shifts in the VAR model.

Table 8. Structural Breaks Test Results

<i>Qu-Perron Procedure</i>	
Tests	Statistics
SupLR	600.16*
WDmax	255.55*
Seq (2/1)	185.62*
Seq (3/2)	223.54*
<i>Estimated Breaks</i>	
Break Dates	95% C.I.
November 1989	(October 1989, December 1989)
October 2000	(September 2000, November 2000)
October 2009	(September 2009, November 2009)

Notes: * denotes significance at 1%. SupLR tests the null of no breaks versus the alternative of 3 breaks. WDmax tests the null of no breaks against the alternative of unknown number of changes up to 3 breaks. Seq (2/1) tests the null of 1 break against the alternative of 2 breaks. Seq (3/2) tests the null of 2 break against the alternative of 3 breaks.

Accounting for these shifts in regimes, we can identify the impulse responses specific in each regime. Unlike the first exercise, where the VAR model is assumed to have a constant conditional mean (and consequently the responses are constant over the sample), when accounting for the shifts in the conditional of the VAR model we identify relatively different responses to fall in sovereign share. Figs. 6, 7, 8 and 9 depict these responses for regimes 1, 2, 3 and 4 respectively.

Fig. 6. Expected excess returns and asset shares responses to fall in sovereign share

Form 3- regime 1 (1984m1-1989m11)

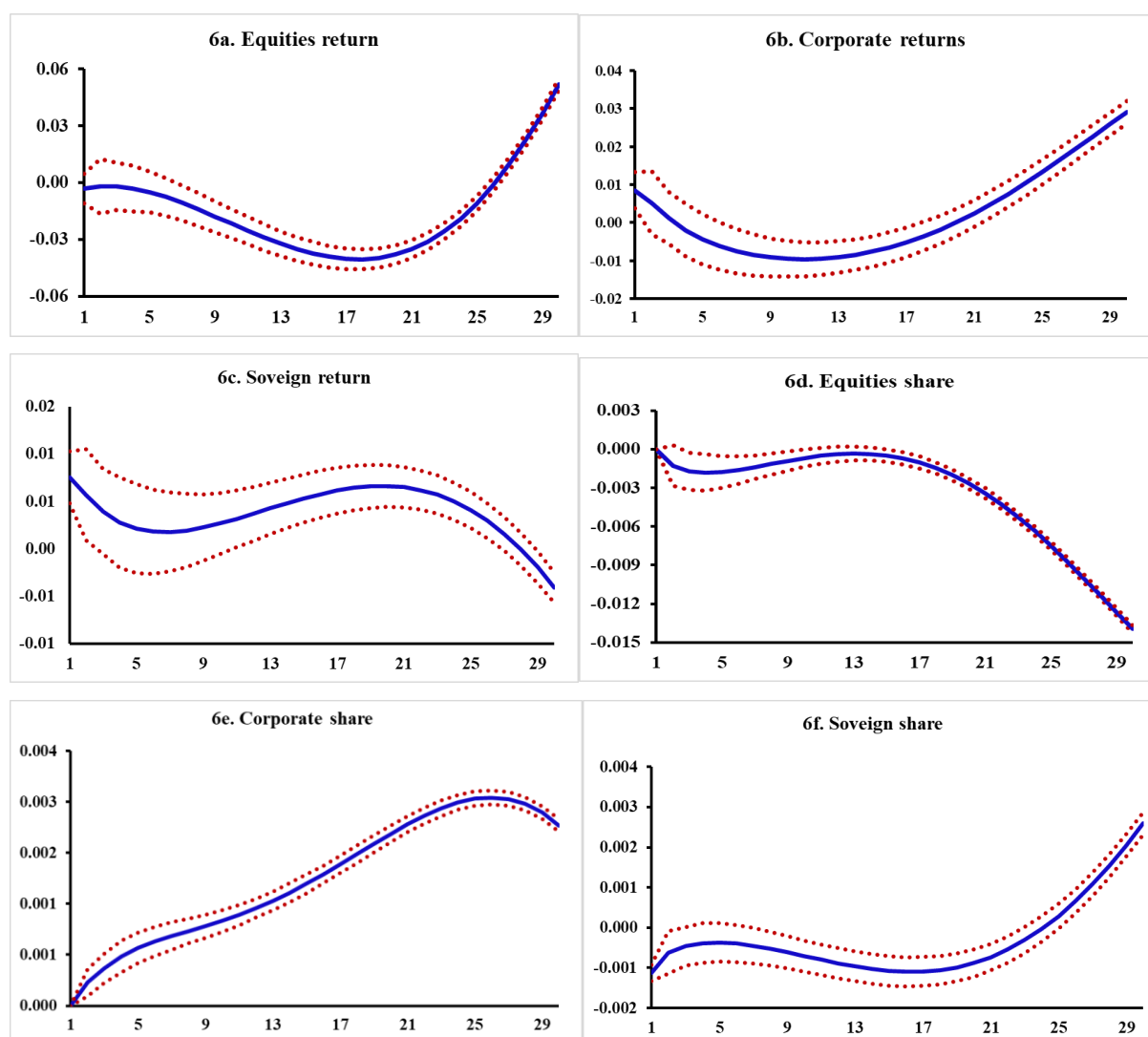
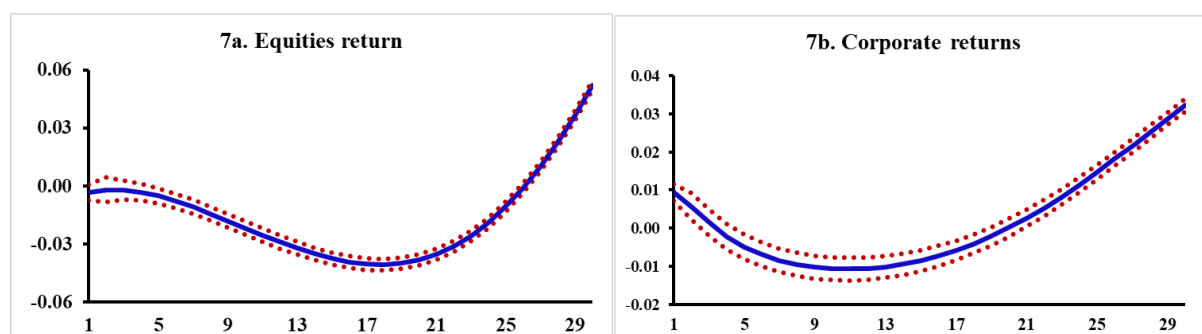


Fig. 7. Expected excess returns and asset shares responses to fall in sovereign share

Form 3- regime 2 (1988m12-2000m10)



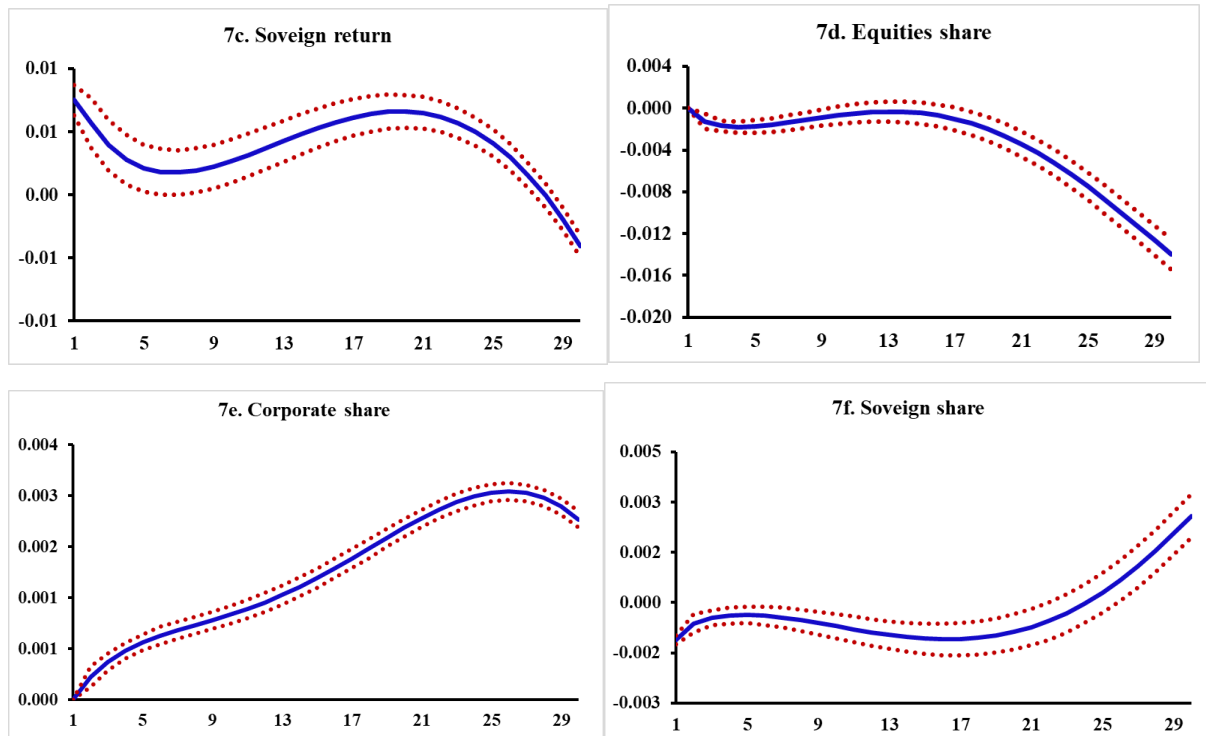
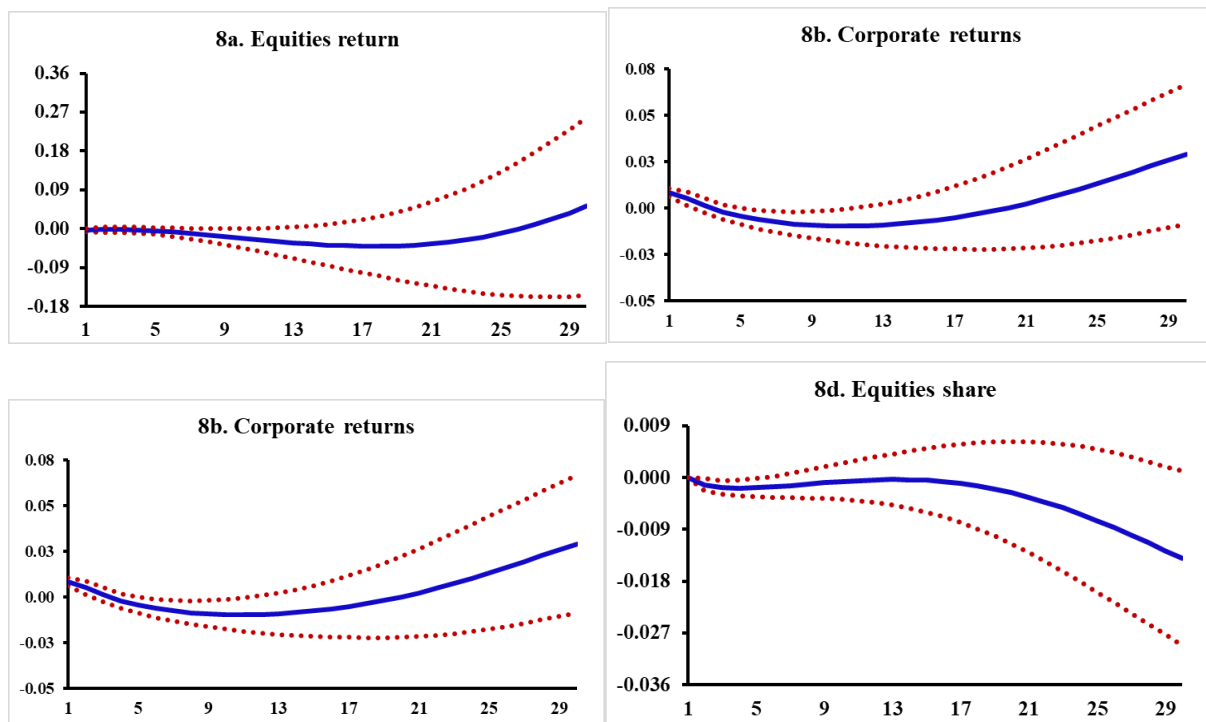


Fig. 8. Expected excess returns and asset shares responses to fall in sovereign share
From 3-regime 3 (2000m11-2009m10)



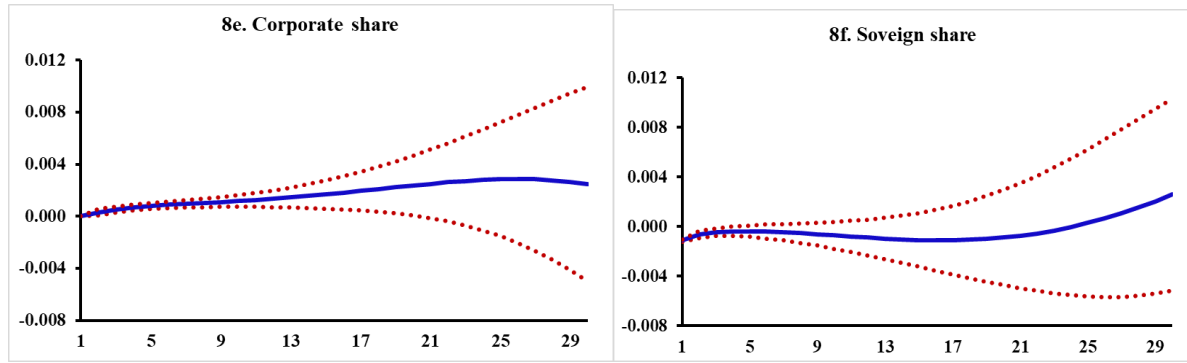
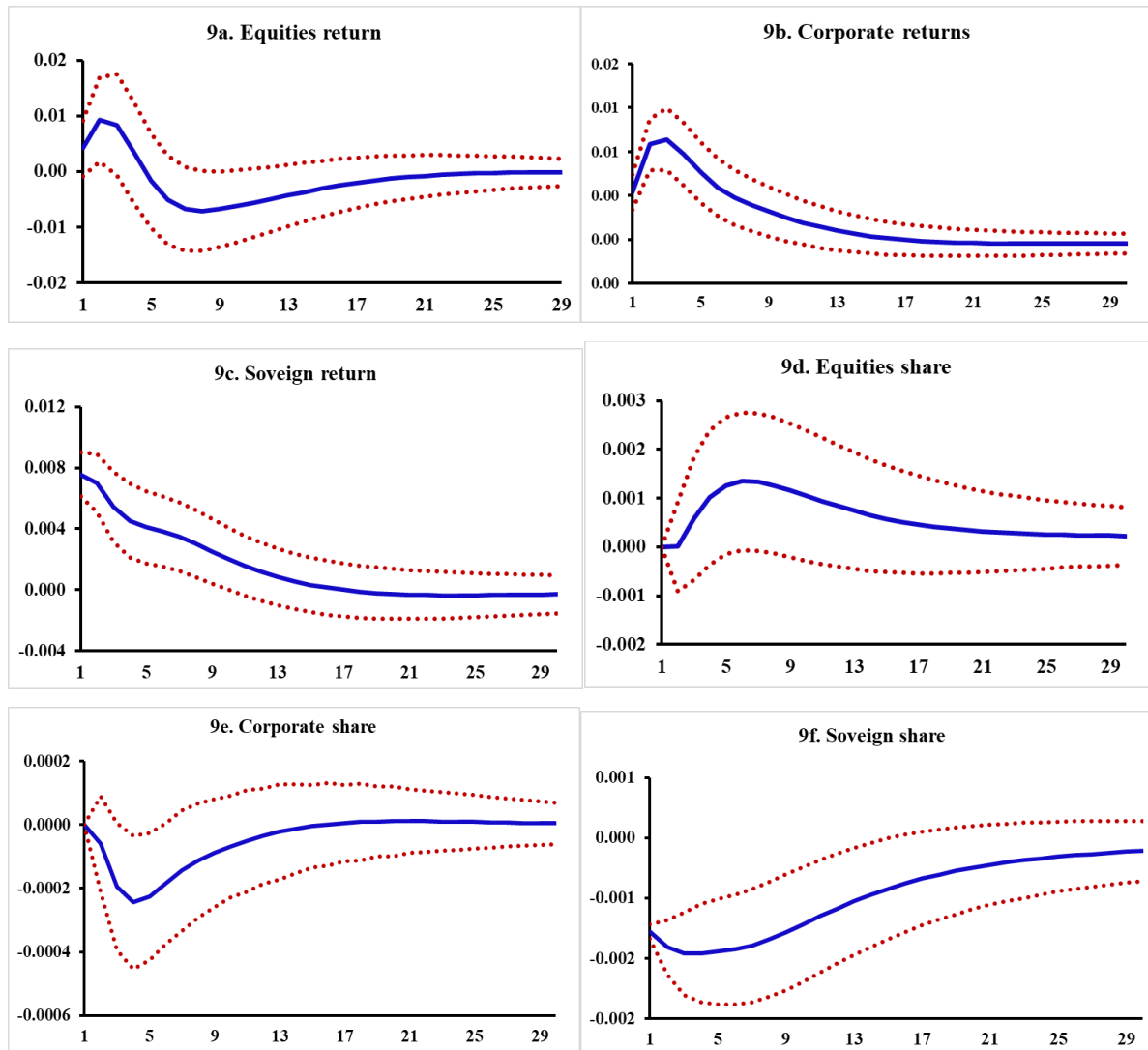


Fig. 9. Expected excess returns and asset shares responses to fall in sovereign share
Form 3-regime 4 (2009m11-2017m01)



According to the IRFs, accounting for regime shifts does leads to different behaviour across regimes. For example, returns and share series exhibit a highly persistent behaviour during regimes 1 to 3, which shows that the stock market transmitted shocks are persistent over time (e.g. do not die off over the time horizon). Moreover, this also suggests that the level of and

return on shares behave in a similar manner in these regimes. In terms of the magnitude and sign, regimes 1 and 2 (Fig. 7 and 8) display higher persistence, while regime 3 (Fig. 8) seems to have a relatively stable dynamic before exhibiting a tendency to persist over time. In addition, the responses of the returns to monetary shocks are negligible for regime 3. This could be because regime 3 covers some part of QE1. Regime 4, as depicted in Fig. 9, shows similar patterns to those in Fig. 4a-4c. Regime 4 represents the period where the shifts in the stock market can be viewed as driven by various QE announcement. The shocks in equity, corporate and sovereign returns decline quickly and die off eventually. In contrast, equity and sovereign shares show a slow return to the long run, while corporate shares exhibit a quick recovery from a negative shock. The overall observation from this empirical exercise is that the regimes that coincide with QE programmes (including regime 4) respond consistently to them, while regimes coinciding with other economic and financial events (such as regimes 1 and 2) do not. This suggests that unconventional monetary policy is successful in achieving the aims of the Fed.

7. Conclusion

The results provide evidence for a direct effect of QE induced by the portfolio balance channel on returns of sovereign bonds, in addition riskier assets such as corporate bonds and equities. Our estimates formally support to the widespread belief that QE in the US has a substantial positive influence on equity prices. The findings suggest that QE shocks induce negative impacts on the ERP and leads to higher S&P 500 returns. Interestingly, equity returns appear to evidence a slower pace of adjustment and therefore a slower reversal of price reaction than US Treasuries, demonstrating a slower feedthrough of the portfolio balance channel to riskier assets. Particularly remarkable though, is the finding that QE effectively increased equity prices by 9.6%, mainly due to a lowering of the ERP. This demonstrates that the portfolio balance channel has a direct impact on equities' rate of return in excess of that on sovereign bond yields. The price increase described therefore solely stems from a readjustment of the equity yield through the risk premium. Moreover, our empirical findings indicate that before and after the implementation of QE, the monetary policy shocks have a negative effect on the ERPs of the aggregate market. However, a negative response of the ERP leads to higher returns of the S&P 500 with QE. The empirical evidence provided in the paper sheds light on the equity market's size asymmetric response to the Fed's policy with and without QE.

Moreover, while much of the literature assume – either implicitly or explicitly – that the conditional mean of the VAR model is constant over the sample, we find evidence that the VAR

specification of relax this assumption and assess the stability of the relationship between government bonds, investment-grade corporate bonds and equities is not stable of the sample, three breaks have been identified that include key economic events. This has various implication on policy. First, the dynamics of the market is found to be unstable and may lead to different policy regimes. In the context of our findings, the long run relationship was not driven only by QE programmes. Second these policy regimes are described by different events and different policy implementation approaches. While the first two regimes are characterised by traditional approach to monetary policy, Regime 4 is consistent with the emergence of QE and the unconventional policy approach. Third, crises pre-2007 have significant impact on the balance portfolio channel. According to our findings, pre- QE regimes experienced persistent shocks, while the regime that coincide with the QE programmes exhibit quick recovery in most cases. This may indicate the effectiveness of QE in reducing the uncertainty in the market as opposed to traditional monetary policy intervention.

Therefore, the results of this paper suggest that QE can improve financial market liquidity. Our conclusion is that QE has played an important role in conducting monetary policy in the US in much the way that was anticipated and intended. In a world with highly interconnected capital markets, QE is likely to have contributed to a portfolio reallocation and re-pricing of financial securities on a global level (Fratzscher et al., 2012). Even though the empirical findings of this paper are unlikely to have captured the full effects of QE and its exact consequences on equity returns, the portfolio balance channel nevertheless proves to be a powerful in reducing the required rate of return on a range of assets displaying different risk profiles.

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Appendix

Fig. F1. Residual Test for Autocorrelation Correlograms (2 Std. Error Bounds)

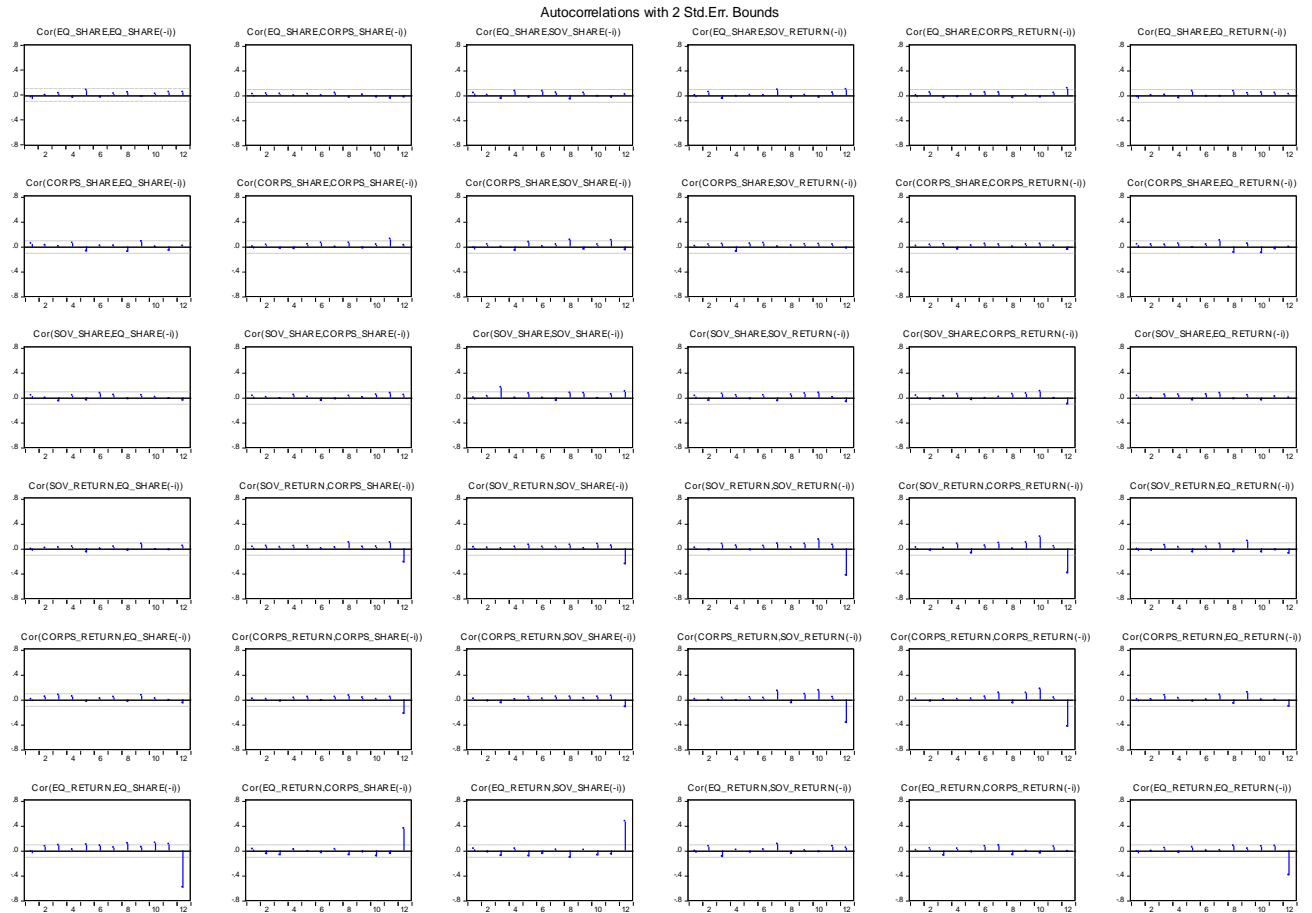


Table T1. Variance-Covariance matrix Σ_u of the VAR model*

	Sh. of Equities	Sh. of Corp. Bonds	Sh. of Sov. Bonds	ER on Sov. Bond	ER on Corp. Bonds	ER on Equities
Sh. of Equities	0.87	-0.12	-0.24	-0.14	0.30	3.65
Sh. of Corp. Bonds	-0.12	0.03	0.03	0.15	0.15	-0.44
Sh. of Sov. Bonds	-0.24	0.03	0.10	0.25	0.14	-0.86
ER on Sov. Bonds	-0.14	0.15	0.25	7.14	7.92	1.35
ER on Corp. Bonds	0.30	0.15	0.14	7.92	11.77	5.39
ER on Equities	3.65	-0.44	-0.86	1.35	5.39	38.71

*Note (1): 'Share' abbreviated as 'Sh.' and excess return as 'ER'

Table T2. VAR stability condition and Lag-Length Criteria

VAR without Dummy	
Root (Maximum)	0.9933

SC (Selected Lag)	-39.58 (2)**
HQ (Selected Lag)	-39.84 (2)**
AIC (Selected Lag)	-40.08 (2)**

*Note (1): ** 5% significance level

Table T3. Residual test for autocorrelation LM test for VAR

	LM Test Statistic	P-Value
Lag 1	39.46	0.32
Lag2	30.28	0.73
Lag 3	77.19	0.01

Table T4. Jarque-Bera test for univariate normality

	Norm (1)	Skewness	Kurtosis
<i>Excess Return on Equities</i>	199.86***	1.02***	6.59***
<i>Excess Return on Corp. Bonds</i>	978.86***	0.97***	11.93***
<i>Excess Return on Sov. Bonds</i>	157.5***	0.52***	6.51***
<i>Share of Equities</i>	6.89**	-0.23	3.60**
<i>Share of Corp. Bonds</i>	667.05***	-0.39***	10.51***
<i>Share of Sov. Bonds</i>	5.76*	-0.11	3.66**
<i>Joint</i>	2015.94***		

Table T5. Scaling of one standard deviation IRFs to size of QE programmes

	Start of Purchases	Barclays Market Value*	Treasury Securities Outstanding*	Ratio	One Stdev*	Scaling
QE 1 (\$300 bn)	Mar-2009	3080	11126	3.61	866	0.10
QE 2 (\$600 bn)	Nov-2010	5211	13861	2.66	1168	0.19
QE 3 (\$755 bn)	Sep-2012	6067	16066	2.65	1386	0.21

Source: Thomson Reuter's Datastream, *Fawley & Neely (2012)*

*Note (1): Values in Billions of US Dollar \$

Table T6. Regression output from Equation 10

Variable	Coefficient	Std. Error	t-Statistic	P-Value
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$\Delta ERP_{t,t-1}$	-4.14	0.12	-34.91	0.00
c	0.07	0.01	18.06	0.00
R^2	0.75			

Equation E1: The Log-Likelihood Ratio

$$\lambda = (T - m)(\ln|\Sigma_r| - \ln|\Sigma_u|) \sim \chi^2(q)$$

T = number of observations

m = number of parameters in each equation

$|\Sigma|$ = determinant of the residual's covariance matrix (restricted and unrestricted)

q = degrees of freedom of Chi-Square distribution

$$\begin{aligned}\lambda &= [281 - (6 * 1 + 3 + 2)](\ln(0.14) - \ln(0.11)) = \\ &= 270 * (0.25) = 68.13\end{aligned}$$

Source: Chi-Square Distribution Table, Lütkepohl (2013)